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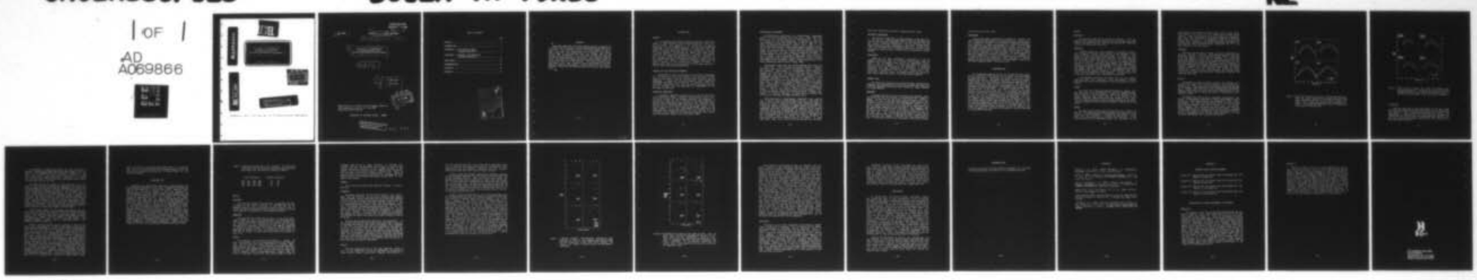

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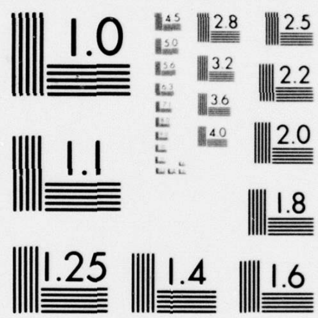

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THE EFFECT OF A HEARING LOSS
ON SIGNAL DETECTION AND
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(11) MAY 1979

(9) DCIEM Technical Report NO. 79X13

(14) DCIEM-TR-79X13

(6) THE EFFECT OF A HEARING LOSS ON SIGNAL DETECTION AND FREQUENCY DISCRIMINATION PERFORMANCE.

(12) 25p.

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ABSTRACT

Currently applicants for sonar operator must be classified H1 - hearing level not greater than 30 dB between 500 and 6000 Hz in both ears. It is difficult to find a sufficient number of applicants that meet this requirement, and if possible, the CF would like to lower it to H2 (hearing level not greater than 30 dB between 500 and 3000 Hz). For this reason a study was conducted to compare the performance of individuals with moderate hearing losses and those with normal hearing on auditory tasks similar to those carried out by a sonar operator. The results indicated that individuals with high frequency losses (above 3000 Hz) and with moderate conductive impairments, could successfully do such tasks. Personnel classified H2 should be able to carry out the required tasks.

INTRODUCTION

PROBLEM

It is becoming increasingly difficult to recruit a sufficient number of sonar operators in the Canadian Armed Forces who are in the H1 category. (See appendix A for definitions of hearing categories in the Canadian Forces.) For this reason DCIEM was asked (DPM, Letter Feb 77) to determine if personnel with some degree of hearing impairment could do the auditory tasks required of a sonar operator. In carrying out these tasks both signal detection and frequency discrimination is involved. The operator must be able to detect the presence of a signal or a variation in the reverberation due to the sound bouncing off an object, and to determine if this signal is shifted in frequency away from the centre frequency of the reverberation (doppler shifted). A doppler shift indicates a moving target with the degree and direction of shift giving added information.

HEARING LOSS AND AUDITORY PERFORMANCE

The probability that an individual with a hearing impairment will be able to do these tasks depends on both the nature and the degree of impairment. There are two main types of organic hearing impairment - conductive and sensorineural. With a conductive impairment, the outer and/or middle ear is affected. With sensorineural impairment, the inner ear and/or the eighth auditory nerve is involved. Often the impairment is a combination of the two types of pathology.

Conductive Impairment

A conductive impairment results only in a loss of sensitivity (Davis and Fowler, 1964). Frequently, the degree of loss is similar across the whole of the frequency spectrum. (An exception is otosclerosis where the loss is limited to the lower frequencies.) Hearing can be improved by amplification of the incoming sounds (Berger, 1971). Therefore, the capability of a person with a conductive loss should be limited only by the dynamic range of the sonar system. In a noisy environment, if the spectrum of the background noise matches the pattern of their hearing loss an individual with a conductive loss may even do better than a normal hearing individual (Dudok de Wit & Dishoeck, 1964).

Sensorineural Impairment

The hearing loss associated with sensorineural impairments usually varies with frequency (Davis and Fowler, 1964). Most commonly, e.g. noise induced hearing loss and presbycusis, the loss is limited to the high frequencies. If the loss is limited to those frequencies above the speech range of 400 to 3000 Hz, the effect on auditory functioning is minimal (Davis, 1964). If the loss extends down into the speech range, however, speech discrimination can be affected. The high frequency components of many sounds are inaudible, and the listener must discriminate among the sounds using only the lower freqency information available. If the environment is noisy the task becomes even more difficult. Thus a person with a sensorineural impairment usually functions less effectively than a normal hearing person in a noisy environment (Dudok de Wit & Dishoeck, 1964). A sensorineural loss is not always improved by amplification (Plomp, 1978).

Sensorineural impairment may include symptoms other than loss of sensitivity. These include recruitment, binaural or monural diplacusis, and loss of ability to discriminate words, syllables and sentences. Recruitment is an abnormally rapid increase in loudness as a function of intensity so that the range of intensity between too soft and too loud is very small. Diplacusis is a derangement of pitch sensation. With diotic diplacusis a tone presented alternately to the two ears is judged to have a different pitch in each ear while with monaural diplacusis a single pure tone is heard as a group of tones or a buzz (Schuknecht, 1970). These types of impairments are not necessarily correlated with a hearing level. In fact, with a lesion of the auditory cortex it is possible to sustain impaired speech discrimination without a loss of sensitivity for pure tones (Schuknecht, 1970). If pitch perception, speech discrimination, and/or loudness perception is severely impaired, an individual will probably have difficulty in carrying out complex auditory tasks.

Individuals with a sensorineural impairment that involves only a loss of sensitivity above 3000 Hz should, in principle, be able to carry out the required auditory tasks, where the range of frequencies being listened to is always between 500 and 3000 Hz. If the task requires perception of complex auditory patterns with components both above and below 3000 Hz, however, the H2 category individual may be at a disadvantage. An individual with a loss of sensitivity below 3000 Hz should be able to do an auditory task in which the frequency range of the auditory stimuli is narrower than the frequency range across which the hearing threshold is elevated, with additional amplification of the stimuli. If symptoms other than loss of sensitivity were present the individual

would have difficulty carrying out complex auditory tasks.

Unilateral Impairment

The degree of impairment is often different in the two ears. If one ear has close to normal hearing then the individual can usually function quite adequately unless a task requires that each ear receive different information. Most sonar systems present returns diotically (same information to each ear). In this situation, an individual with a unilateral hearing loss should be able to perform a required task as effectively as a person with normal hearing.

Conclusions

Based on the above information, individuals in the H2 category should be able to carry out auditory tasks, when the stimuli fall in the speech range, as well as individuals classified in the H1 category. In fact, individuals classified H3 should be able to do these tasks if the information is presented diotically (the same information to both ears). If different information is presented to the two ears (dichotically), they would have problems unless the dynamic range of the system was sufficient to make the stimuli in the impaired ear audible.

CURRENT STUDY

The aim of this study was to confirm the above conclusions by comparing the performance of normal hearing people and those with a hearing impairment on auditory tasks similar to those required of a sonar operator.

Observers

It proved difficult to recruit observers with moderate hearing losses who could participate in an experiment over a number of months. To date only two individuals have been found. The first, observer B, had a bilateral high frequency (above 2000 Hz) sensorineural loss (with the left ear being somewhat poorer) and a severe conductive deficiency in the right ear of approximately 60 dB. The second, observer S, had a bilateral low frequency sensorineural loss of about 30 dB in both ears, a high frequency sensorineural loss in the left ear and a moderate conductive loss in the left ear. (For a more detailed description of the hearing losses of the two observers see Appendix B.) Both subjects would be classified H3. However, they both had losses above 3000 Hz. Thus, if they could do the tasks, individuals classified H2 should

also be able to do such tasks.

Experiments

The two experiments reported here attempted to simulate the signal detection and frequency discrimination tasks a sonar operator is required to perform. In the detection experiment observers were required to detect the presence of a signal in narrow band noise which simulated the reverberation of a sonar ping at 1000 Hz. Detection was measured with the signal centered in the band of noise and with the signal shifted as much as 40 Hz above or below the centre frequency of the noise band. The second experiment measured frequency discrimination capability in the presence of the narrow band noise. On each trial observers were presented with a signal at one of four frequencies. Their task was to indicate whether the tone presented was one of the two higher or one of the two lower frequency tones in the set of four.

EXPERIMENT ONE

This experiment compared the ability of observers with normal hearing and those with a hearing loss to detect a sinusoid masked by narrow band noise. Performance was measured with the signal frequency the same as, and shifted away from, the centre frequency of the masker. At each frequency, performance was measured for a number of different signal to noise ratios (S/N). The highest S/N used was that giving 100 percent performance while the lowest resulted in chance performance. The experiment was repeated under two conditions. In the first, the diotic condition, the same stimuli were presented to both ears. In the second, the monaural condition, the stimuli used in the diotic condition were presented to one ear and an independent masker was presented to the contralateral ear to prevent its being used for detection. The signal maskers were inaudible to the hearing loss observers, at the intensities normally used, when presented only to their ear with the greatest impairment (right ear for B and the left ear for S). To assess performance under this condition, the amplitudes of the signal and the maskers were increased - 29 dB for observer S and 39 dB for observer B. The S/N at the observers' ears was the same as in the other conditions.

METHOD

Observers

Four observers took part in the diotic condition - the two hearing loss observers described earlier and two observers, both female, with normal hearing. Only the two hearing loss observers carried out the monaural condition.

Apparatus

A PDP8-I computer was used to generate a sinusoid at a specified frequency. Before being passed to the earphones, it was gated on and off with 100 millisecond ramps, to produce a tone burst in each of two observation intervals. The signal was then passed through a switch that was on in one of the two intervals and off in the other. The selected interval was randomly changed from trial to trial. The narrow band masker was generated by passing a wide band noise through the 50 Hz wide filter of Spectral Dynamic's dynamic analyser #SD101B. The masker was pretaped and played back at runtime to the two earphones after being attenuated to the required intensity. A low intensity wide band noise was also presented to both earphones. The amplitude of the signals and the maskers were independently adjustable.

In the monaural condition, the signal and the two maskers described above were presented to only one earphone. A second wide band noise source was presented to the contralateral ear as a masker.

Signal

The signal was a tone burst 500 milliseconds in length. During each run, it was presented at one specific frequency between 940 and 1060 Hz at a fixed intensity. Under most conditions, the signal intensity used ranged from 44 to 60 dB SPL. In the monaural condition, where the stimuli were inaudible to the hearing loss observers because of their elevated threshold, the signal intensity ranged from 73 to 90 dB for observer S and 83 to 100 dB for B.

Masker

The masker was a narrow band of noise 50 Hz wide centred at 1000 Hz. Its amplitude was fixed throughout most conditions at 40 dB per Hz or at 57 dB overall. To mask out transients, a wide band noise was presented at 10 dB/Hz (30 dB overall). In the monaural condition, an independent masker was presented to the

contralateral ear to prevent this ear's being used in the detection process. The level of this masker was 60 dB/Hz (80 dB overall). Since a wide band noise of this intensity is uncomfortably loud, the non-critical frequencies below 700 Hz and above 1300 Hz were filtered out. In the monaural condition in which the stimuli were inaudible at the normal intensities, the maskers in the signal ear were elevated 29 dB for S and 39 dB for B - the same increase as for the signals.

Procedure

Each day, four sessions of three runs were completed per observer. During a session, observers were seated in separate sound proof booths. A run consisted of eighty trials. On each trial the observer's task was to indicate, by pressing the appropriate button, in which of two successive intervals of time he or she thought the signal had occurred. A trial consisted of a 200 millisecond warning interval, two 500 millisecond observation intervals separated by a 600 millisecond pause, and a one second response interval. The four intervals were marked by lights located on a panel in front of the observer. At the end of each trial, the same lights indicated which observation interval had contained the signal.

RESULTS

Performance in terms of percent correct was plotted as a function of signal level for each observer, at each signal frequency tested. From these curves, the signal levels that resulted in 75 percent and 90 percent at each frequency were determined. Figure 1 shows these results for the diotic condition for all four observers, while Figure 2 shows the results in the monaural condition for S and B.

Performance was similar for all observers in the diotic condition. In the monaural condition, S and B's performance in their better ear, without amplification, was identical to their diotic performance. By amplifying the stimuli 29 dB, S was able to get equivalent performance in her left or poorer ear. B's performance, however, was much poorer and very erratic even with this level of amplification. With the levels of the stimuli increased an additional 10 dB, his performance in the right ear was within 2 dB of his performance in the left ear except at 1036 Hz. At this frequency, performance was 7 dB worse than normal.

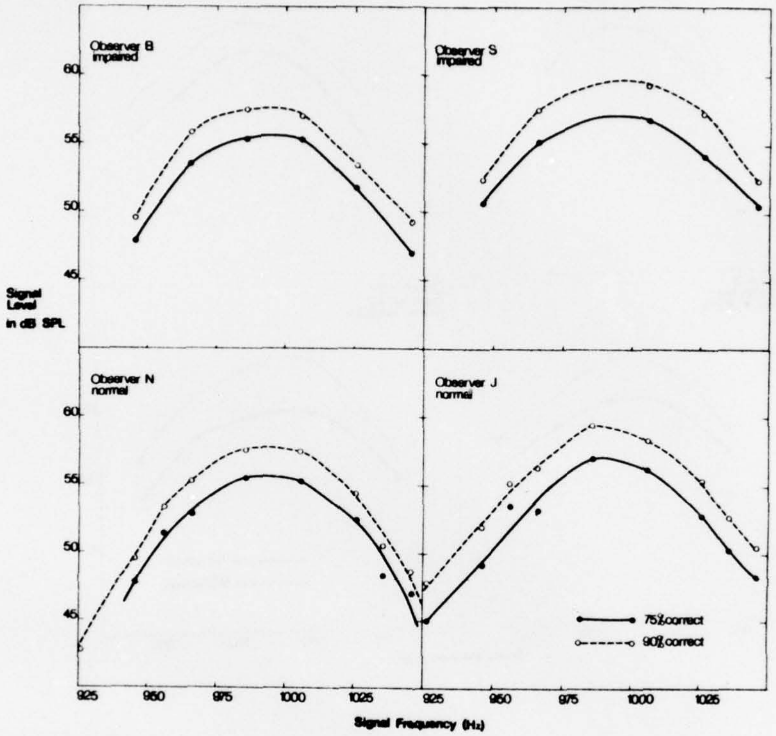

Figure 1: Signal level necessary to achieve 75% and 90% detection, when the signal is masked by a narrow band noise 50 Hz wide, centered at 986 Hz, as a function of signal frequency. The signal and maskers were presented diotically. The narrow band masker was fixed in intensity at 40 dB per Hz (57 dB overall).

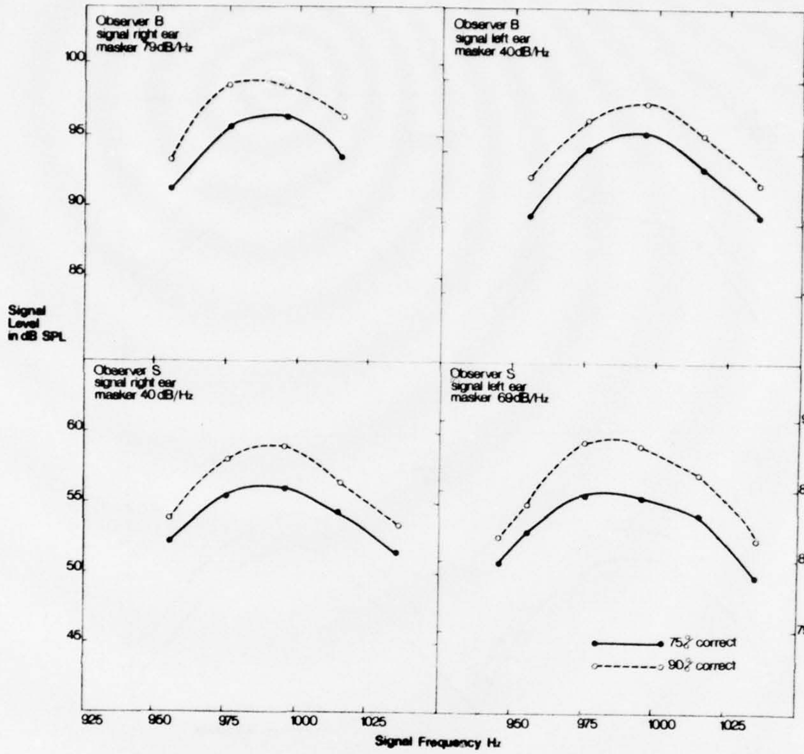

Figure 2: Same as Figure 1 except the signal and maskers were presented monaurally. The masker was fixed at 89 dB per Hz when presented to the left ear of observer B and 79 dB per Hz when presented to the right ear of observer S.

DISCUSSION

There are three ways in which performance on this task might have differed between the normal hearing observers and the hearing loss observers. Overall performance might have been poorer; the improvement in detectability as the frequency of the signal was shifted away from that of the noise might have been smaller; or, the rate at which performance improved with increasing S/N ratio might have been different.

If performance in general was poorer, the S/N necessary to achieve 75 percent performance would have been higher at all frequencies. This happened only with observer B (Figure 2), and then, only when the signal was presented monaurally to his right ear in which he has a 60 to 70 dB loss. Even with the overall level of the stimuli increased by 39 dB, performance was not equal to that found with the left ear.

The detectability of a signal in narrow band noise is a function of the separation between the frequency of the signal, the centre frequency of the noise, and the bandwidth of the noise. The curves shown in Figure 1 are typical of the detectability of a signal between 930 and 1060 Hz masked by a 50 Hz wide band of noise. Individuals vary in their ability to "reject" the masking noise when the signal is above or below the centre frequency of the noise. Both the hearing loss and the normal hearing observers showed a similar capability along this line in the diotic condition. Observer B failed to show a continuous improvement in performance in the monaural right ear condition on the high frequency side of the noise band. Thus, he would have problems, relative to normal observers, in detecting doppler shifted signals.

The difference between the 75 percent curve and the 90 percent curve in Figure 1 is a measure of the rate at which detectability of the signal increases with increasing signal to noise ratio. For this task, the signal must be shifted about 2 dB for performance to improve from 75 percent to 90 percent. All observers showed a similar rate of improvement both in the monaural and diotic condition.

Overall, the high frequency loss of observers S and B did not affect their performance. As well, S was able to carry out the task, with additional amplification, despite a 40 to 50 dB conductive loss in her left ear. However, it was not possible to totally compensate for B's conductive loss of 60 to 70 dB in his right ear. Part of his problem may have been due to masking of the stimuli in the signal ear by the noise in the contralateral ear. The contralateral masker would have had a sensation level of 25 to 30 dB in the signal ear. If the narrow band noise had a similar sensation level at this point, the result would be an increase in the effective signal masker of up to 3 dB at the centre frequency of the noise. The effective masker would never be less than the contralateral masker. Thus, performance at other frequencies would differ from that found for the centre frequency by about 3 dB at most. To date it has not been possible to test this hypothesis experimentally. The results shown in Figure 2 for Observer B do not support the existence of a contralateral masker

equal in intensity to the narrow band masker, but it is possible that the 1 to 2 dB difference in performance between the the two ears is due to contralateral masking. It cannot account for the results at 1036 Hz.

EXPERIMENT TWO

Experiment two compared the capability of normal hearing and hearing impaired observers to carry out a frequency discrimination task in the presence of a narrow band noise. Observers were required to discriminate amongst a set of four frequencies by stating whether the current signal sample being presented was one of the two high frequency signals or one of the two low frequency signals in a population of four. For instance, in the signal population 936, 946, 976, and 986 Hz, 936 and 946 Hz would be classified as low frequency, 976 and 986 Hz as high frequency. To correctly label 936 Hz as low, it must be discriminated from 976 Hz - a separation of 40 Hz. Similarily, to label 986 Hz as high, it must be discriminated from 946 Hz also a separation of 40 Hz. Thus the number of times these two are correctly labelled is a measure of frequency discrimination at 40 Hz separation at those frequencies. To correctly label 946 as low the observer would have to be able to discriminate it from 976 Hz and vice versa. The number of correct identifications for these two is a measure of frequency discrimination performance for a separation of 30 Hz at those frequencies. Performance was compared at a number of different frequencies and frequency separations. Table 1 gives the frequency sets and the corresponding frequency separations used.

TABLE 1: Signal populations used in the frequency discrimination experiment and the frequency separations associated with each population. The noise was centered at 986 Hz.

Signal Population				Frequency Separation	
956	976	996	1026	20	50
936	946	976	986	30	40
986	996	1036	1046	40	50

METHOD

Observers

The same four observers that took part in experiment one participated in the diotic condition of experiment two. For the monaural condition, one of the normal hearing observers was no longer available. Two new normal hearing observers were recruited, for a total of five observers in the monaural condition.

Apparatus

The apparatus was essentially the same as in the first experiment except for the signal presentation. At the beginning of each run, the experimenter specified to the computer the four signal frequencies to be presented during the run, and the amount each was to be attenuated. On each trial, the computer generated a sinusoid at one of these four frequencies, and attenuated its amplitude the amount specified. The sinusoid was then gated on and off to produce a signal during the observation interval of each trial.

Signal

The signal was a sinusoid 500 milliseconds in length. On each trial within a run, it was presented at one of four frequencies. The four tones were usually presented at different amplitudes during the run. If they had been at the same amplitude, they would not have sounded equally loud, and it would have been possible to discriminate the tones on the basis of loudness as well as frequency. With a narrow band masker, signals near the center of the masker sound softer than signals higher or lower in

frequency, when all are of equal intensity. To overcome this problem, the data from experiment one (as shown in Figure 1) were used to adjust the intensity of the signals relative to one another so that they would be equal in detectability. Hopefully, this resulted in the signals' sounding equally loud. Based on observer report and the results obtained, this adjustment at least made it easier to discriminate the signals on the basis of frequency than loudness.

Maskers

In all cases the maskers were identical to those in experiment one.

Procedure

The general procedure did not differ from the first experiment, but the task did. On each trial, observers were asked to indicate whether the tone they heard was one of the high frequency or one of the low frequency tones being presented during that run. A trial consisted of a 200 millisecond warning interval, a 500 millisecond observation interval, and a one second response interval. The observer responded by pushing button one for low frequency and button two for high frequency on a button box. At the end of the trial, the correct button was illuminated to indicate the right response. For each group of frequencies, performance was measured at several different S/N. Performance was also measured without the narrow band masker with signal intensity fixed at 60 dB SPL.

The task was presented both diotically and monaurally. In the diotic condition the same stimuli were presented to each ear. In the monaural condition the signal plus maskers were presented to one ear and a wide band noise was presented to the contralateral ear. The overall level of the signals plus maskers was increased 29 dB before being presented to the hearing impaired observers in the monaural condition to make the stimuli audible to them. (At the time this experiment was run, 29 dB was the maximum increase in amplitude possible.) The monaural condition was run in one ear only. For the hearing loss observers this was the ear in which they had the greatest impairment.

RESULTS

Since the signals were not at the same amplitude during a run, it was impossible to look at performance as a function of signal level or signal to noise ratio. However, the intensity of

the tones had been modified to make them equally detectable within a run. Therefore, performance was plotted as a function of signal detectability for each frequency separation and each observer. These curves were then used to derive Figures 3 and 4.

Figure 3 shows the maximum frequency discrimination achieved at each frequency separation for each subject with and without the narrow band masker present. When the narrow band masker was present the S/N was large enough that the tones were clearly audible. For most observers, peformance was similar with and without the narrow band noise present with the observers achieving 100 percent performance when the tones were separated by more than 30 Hz. The main exception was observer J who was never able to consistently discriminate the tones from one another even at the widest frequency separations used.

Figure 4 shows the detectability of the tones when they could be discriminated on the basis of frequency 75 percent of the time, as a function of frequency separation and frequency. The results give a measure of the effect of the narrow band masker on frequency discrimination. Two results stand out. First, there was considerable intersubject variability. Observers N and B (in the diotic condition) achieved 75 percent frequency discrimination when they could detect the signals only 80 percent of the time (at frequency separations where they achieved 100 percent frequency discrimination). Other observers (ie., H and J) did not reach the 75 percent performance level on the frequency discrimination task until the signals were detectable close to 100 percent of the time. Secondly, performance in noise was not only a function of frequency separation, but also a function of the frequency of the tones relative to the centre frequency of the narrow band masker. If the tones where all below the centre frequency of the noise (points labelled "L") or centred around the centre frequency ("C"), performance was usually superior to performance when the tones were all above the centre frequency of the noise ("H"). It is not clear whether this result is an experimental artifact or if it is related to the use of the narrow band masker. Further experimentation would be necessary to clarify this.

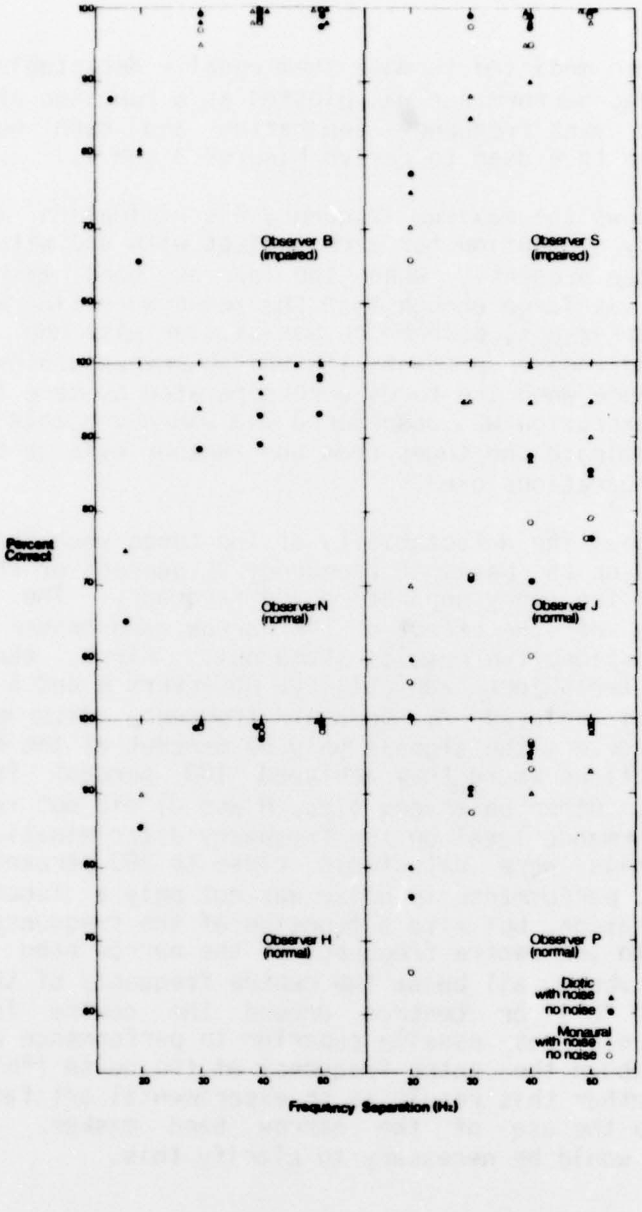

Figure 3: Maximum frequency discrimination achieved by each observer at each of the frequency separations tested with and without the narrow band noise present. The results are shown for both the diotic and the monaural conditions.

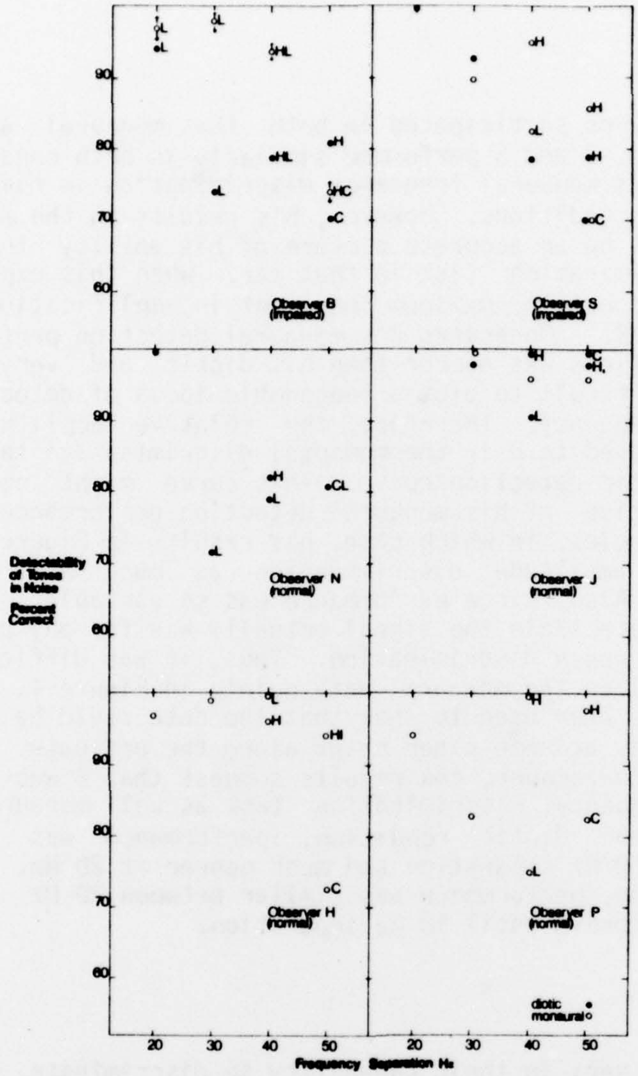

Figure 4: Detectability of tones at the signal to noise ratio at which they could be discriminated on the basis of frequency 75% of the time. Performance is shown as a function of frequency separation for both the monaural and diotic conditions. In the monaural condition, the stimuli were 29 dB louder than in the diotic condition for observers B and S.

Three observers participated in both the monaural and the diotic condition. J and S performed similarly in both conditions, while observer B's monaural frequency discrimination in noise differed in the two conditions. However, B's results in the monaural condition may not be an accurate picture of his ability to do a frequency discrimination task in that ear. When this experiment was being carried out the maximum increment in amplification possible was 29 dB. Observers B's monaural detection performance under such conditions was poorer than his diotic and very variable. It was difficult to plot a reasonable locus of detection as a function of frequency. Therefore, the relative amplitudes of the tones presented to B in the monaural discrimination task were based on his diotic detection curve. This curve might not have been representative of his monaural detection performance at the different frequencies, in which case, his results in Figure 4 were a function of amplitude discrimination as much as frequency discrimination. Also, since performance was so variable, it was not clear how detectable the signal actually was for any particular level of frequency discrimination. Thus, it was difficult to know where to place the monaural data points in Figure 4. Therefore, arrows have been used to show that the data could be plotted just as reasonably at some other point along the ordinate. Taking these factors into account, the results suggest that B was unable to do the frequency discrimination task as well monaurally as diotically. In the diotic condition, performance was similar between 30 and 50 Hz separation and much poorer at 20 Hz. In the monaural condition, performance was similar between 20 Hz and 40 Hz and did not improve until 50 Hz separation.

DISCUSSION

Individuals vary in their capability to discriminate between tones on the basis of frequency. This is clearly seen by comparing the performance of the normal hearing observers. Thus, if observers S and B had been unable to carry out this task diotically it would not necessarily have been because of their hearing loss. However, a substantial difference between monaural and diotic performance could be explained on this basis. Observer B showed such a difference (Figure 4). It would appear that his hearing loss was interfering with his frequency discrimination performance. However, it did not affect his frequency discrimination without noise (Figure 3). Since his detection performance was also impaired under similar conditions, the problem may have been be one of detecting the signals rather than of discriminating them. Without further experimentation it is not possible to draw more definite conclusions.

Performance in general in this experiment was poorer than that found in many other frequency discrimination experiments. These have shown that under certain conditions individuals may be able to discriminate tones separated by as little as one Hz at 1000 Hz. However, in such cases, only two tones are presented and they are presented close together in time. In the present experiment, observers had to rely on their memory of what the four tones sounded like relative to one another and to the narrow band noise in order to make a decision. Under such conditions, much poorer performance would be expected. However, this task was closer to that actually required of an operator than a comparison task.

CONCLUSIONS

For the most part, the results of these experiments support the conclusions made in the introduction. First, an elevated threshold in the range of frequencies outside those being used did not affect performance. B has a high frequency loss at 4000 Hz of 45 to 50 dB in his left ear and his performance was normal without any amplification. Similarily, S has a high frequency loss in her left ear, and she was able to do the tasks once the stimuli had been intensified to compensate for her low frequency loss. Thus, a person in the H2 category should have no problem doing these kinds of tasks. Secondly, both observers, classified H3, were able to do the tasks when the information was presented diotically. Even B's 60 to 70 dB monaural conductive loss did not affect his performance in the diotic conditions. However, B's performance in his right ear was poorer than that in his left ear or his diotic performance on both tasks. His decrement may have been due to the limitations in the dynamic range of the system, or to contralateral masking, or it may indicate a real limitation arising from his hearing loss. In any case, it was not possible to compensate for Observer B's conductive impairment in the monaural condition. Thus, individuals classified H3 could have problems when it came to processing dichotic information.

Based on the information outlined in the introduction, and the findings of this study, any H2 category individual should be able to successfully carry out auditory tasks similar to the ones used in this study. However, if the required tasks utilize auditory stimuli with a wider frequency range than the stimuli used in this study (i.e., include components above 3000 Hz), the individual with an H2 category hearing level might not perform the required tasks as well.

RECOMMENDATIONS

Personnel classified in the H2 category be accepted for training in the sonar operator 281 trade as it is currently specified.

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APPENDIX A

CANADIAN FORCES HEARING STANDARDS

Category H1: Hearing level not greater than 30 dB between 500 and 6000 Hz in both ears.

Category H2: Hearing level not greater than 30 dB between 500 and 3000 Hz in both ears.

Category H3: Hearing level not greater then 30 dB between 500 and 2000 Hz in the better ear.

Category H4: Hearing level not greater than 50 dB between 500 and 2000 Hz in the better ear.

DESCRIPTION OF HEARING IMPAIRMENTS OF OBSERVERS

Observer B

This observer, male, age 25, had both sensori-neural and conductive hearing losses. Hearing was normal in the left ear from 125 to 2000 Hz and at 6000 Hz. Both air-conduction and bone-conduction testing showed a loss of 30-35 dB at 3000 Hz, 45-50 dB at 4000 Hz and 25-35 dB at 8000 Hz. The right ear showed a severe middle-ear impairment with losses on air-conduction tests ranging from 45 to 70 dB. Bone conduction tests, however, showed that sensori-neural impairment in the right ear was minimal from 125 to 3000 Hz with losses of only 5-15 dB. At 4000 Hz there was a 30 dB loss. Speech reception thresholds were 10 dB in the left ear and 58 dB in the right. Unmasked speech discrimination was 100% in the left ear and 92% in the right ear while masked speech discrimination (signal to noise ratio +10 dB) was 84% in the right ear and 76% in the left. This decrement was presumably due to the high frequency loss. To summarize, B had a high frequency sensori-neural loss (above 2000 HZ) in both ears with the left ear being somewhat poorer, and a severe conductive deficiency in the right ear of approximately 60 dB.

Observer S

Observer S, female, age 23, also had a combination of conductive and sensori-neural losses. In the right ear the loss was mainly sensori-neural with a decrement of 30 dB from 500-1500 Hz. Hearing improved at higher frequencies with losses of 15 dB at 2000 Hz, and 5-10 dB from 5000 to 8000 Hz. Air conduction tests on the left ear showed decrements of 45-50 dB from 500 to 2000 Hz, 65 dB at 3000 Hz, 60 dB at 4000 Hz and 55 dB at 8000 Hz. The bone conduction tests, however, showed thresholds of 30 dB from 500 to 2000 Hz, 25 dB at 2000 and 3000 Hz and 20 dB at 8000 Hz. Speech reception thresholds were 45 dB in the left ear and 27 dB in the right ear. Speech discrimination unmasked was 92% in the left ear and 96% in the right and masked was 80% and 84% respectively. In summary, this observer has a low frequency sensori-neural loss of about 30 dB in both ears, a high frequency sensori-neural loss in the left ear and a moderate conductive loss in the left ear.

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